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2000

Online at http://mpra.ub.uni-muenchen.de/24577/
MPRA Paper No. 24577, posted 23. August 2010 02:19 UTC

Early Warning System: Empirical Results from The Signals Approach

Assessing Financial Vulnerability: An Early Warning System for Emerging Markets
Notes from Chapter 3
Morris Goldstein, Graciela L. Kaminsky, and Carmen M. Reinhart
(Washington, DC: Institute for International Economics, 2000)

The signals approach was applied to 24 of the indicators around the dates of the 29 banking and the 87 currency crises. In what follows, we first compare our results for the 15 original indicators in Kaminsky and Reinhart (1996) to those presented in that study. This exercise assesses the robustness of their results as to the individual performance of the indicators. In particular, the sample size has been expanded by including 26 years worth of data for an additional five countries. Second, we examine the performance of many of the indicators that have been stressed in the financial press surrounding the coverage of the Asian crises, including both conventional indicators, such as the current account deficit, as well as indicators which stress the composition of international capital flows.

The monthly indicators: robustness checks

Tables 3.1 and 3.2 present a measure of the reliability of the monthly indicators along the lines presented in Kaminsky, Lizondo, and Reinhart (1998) and Kaminsky (1998) for banking and currency crises, respectively. The variables are shown in descending order in accordance with their marginal predictive power. Hence, for instance, for banking crises the real exchange rate has the greatest predictive power and imports the least. For each indicator, the first column of the tables shows the adjusted noise-to-signal ratio.[1] Hence an indicator with a noise-to-signal ratio of unity, such as those in the bottom of the Tables 3.1-3.2, issue just as many false alarms as good signals. The second column shows the percent of crises (for which there was data for that indicator) accurately called, while the third column lists the probability of a crisis conditioned on a signal from the indicator, $P(C \mid S)$. The fourth column shows the difference between the conditional and unconditional probabilities, $P(C \mid S)-P(C)$, the fifth column shows the ranking the indicator received in the previous "signals" approach analysis, while the last column calculates the difference between its current and previous rank. Hence, a plus 3 in the last column would mean that the indicator moved up three notches as the sample was enlarged, while a minus 2 would reflect a decline in its ranking.

The indicators are ranked on the basis of their marginal predictive power, shown under the heading $P(C \mid S)-P(C)$. The unconditional probability of a banking crisis (not shown) varies from indicator to indicator because of differences in data availability, since not all indicators span the entire sample. Hence, for some indicators the sample is such that the incidence of banking crises is as low as 9.8 or as high as 12. For currency crises, the unconditional

[1] See Kaminsky, Lizondo, and Reinhart (1998) for a description of how these ratios are constructed.

probability is clustered in the 27 to 29 percent range.

Several interesting features stand out from Tables 3.1-2.

First, the ranking of the indicators appears to be quite robust to the selection of the sample, as shown in the last column. The results from the twenty-five country sample match closely the results of the twenty-country sample. This has an important implication as regards the expected out-of-sample usefulness of this approach. Specifically, based on the robustness of the results, it appears plausible to expect that the indicators will have a similar relative predictive ability for countries that are not included in the sample.

Table 3.1. Ranking the monthly indicators: Banking crises

Indicator	Noise-to-signal (1)	Percent of crises accurately called (2)	P(C|S) (3)	P(C|S)-P(C) (4)	Rank in Kaminsky (1998) (5)	Difference in rank (+ denotes and improvement) (6)
1. Real exchange rate	0.35	52	24.0	14.1	1	0
2. Stock prices	0.46	76	23.4	11.2	2	0
3. M2 multiplier	0.46	63	18.3	9.0	3	0
4. Output	0.54	90	17.3	7.2	4	0
5. Exports	0.68	79	14.3	4.2	6	+1
6. Real interest rate	0.68	96	16.8	4.7	5	-1
7. Real interest rate differential	0.73	100	15.6	3.7	7	0
8. Bank deposits	0.73	64	12.9	3.1	8	0
9. M2/reserves	0.84	72	11.4	1.7	9	0
10. "Excess" M1 balances	0.88	44	11.0	1.2	12	+2
11. Domestic credit/GDP	0.89	46	10.9	1.1	10	-1
12. Reserves	0.92	83	10.7	0.8	11	-1
13. Terms-of-trade	1.01	92	11.6	-0.1	13	0
14. Lending-deposit interest rate	1.48	56	8.3	-3.5	14	0
15. Imports	1.75	64	6.0	-4.1	15	0

The authors and Kaminsky (1998).

Table 3.2. Ranking the monthly indicators: Currency crises

Indicator	Noise-to-signal (1)	Percent of crises accurately called (2)	P(C|S) (3)	P(C|S)-P(C) (4)	Rank in K & R (1996) (5)	Difference in rank (+ denotes and improvement) (6)
1. Real exchange rate	0.22	58	62.1	35.2	1	0
2. Stock prices	0.46	66	47.6	18.3	3	+1
3. Exports	0.51	80	42.4	15.0	2	-1
4. M2/reserves	0.51	75	42.3	14.9	4	0
5. Output	0.57	71	43.0	12.5	5	0
6. "Excess" M1 balances	0.57	57	40.1	12.3	6	0
7. Reserves	0.58	72	38.9	12.2	7	0
8. M2 multiplier	0.59	72	39.2	11.6	8	0
9. Domestic credit/GDP	0.68	57	35.6	8.3	9	0
10. Terms of trade	0.74	77	35.4	6.5	10	0
11. Real interest rate	0.77	89	32.0	5.5	11	0
12. Imports	0.87	59	30.1	2.9	13	+1
13. Real interest rate differential	1.00	86	26.1	-0.1	11	-1
14. Lending-deposit interest rate	1.32	63	24.4	-4.8	15	+1
15. Bank deposits	1.32	43	22.3	-5.2	14	-1

Source: The authors and Kaminsky and Reinhart (1996).

Second, some of the most reliable indicators are the same for banking and currency crises. The real exchange rate deviations from trend and stock prices stand out in this regard. Close runners-up are output and exports. A similar statement can be made as regards the least useful indicators, imports and the lending deposit ratio do not have any predictive ability for either type of crisis. It is the case that the a priori or theoretical rationale for analyzing the performance of some of the low scoring indicators is also the most ambiguous.[2]

[2] For instance, lending-deposit interest rate spreads could widen in advance of a crisis due to a deterioration in loan quality or a worsening in adverse selection problems. Alternatively, it could be persuasively argued that ahead of financial crises, banks may be forced to offer higher deposit rates, so as to stem capital flight.

Third, there are some important differences in the ranking of some indicators in currency and banking crises, which suggests that vulnerability takes on different forms. The ratio of M2 (in dollars)/foreign exchange reserves, a variable stressed by Calvo and Mendoza (199x) as capturing the extent of unbacked implicit government liabilities, does quite well (ranks fourth) among the fifteen indicators of currency crises. This indicator is far less useful when it comes to predicting banking crises. Similarly, the money multiplier, real interest rates and bank deposits are of little use when it comes to predicting currency crises. Yet, these indicators score much higher as to their ability to predict banking crises. This result should not come as a surprise, considering two of the variables are strongly linked to financial liberalization, which itself helps predict banking crises. As shown in Galbis (1993), real interest rates tend to increase substantially in the wake of financial liberalization. Furthermore, the steep reductions in reserve requirements that usually accompany financial liberalization propel increases in the money multiplier. Bank runs and deposit withdrawals are at the heart of multiple equilibria explanations of banking crises (see Diamond and Dybvig (19xx)), yet are featured less prominently in explanations of currency crises.[3]

Lastly, if currency crises are difficult to predict, banking crises are even more of a challenge. For currency crises, the marginal predictive power of 10 of the 15 indicators (column three) is five percent or higher and as high as 35 percent for the real exchange rate. By way of contrast, for banking crisis 11 of the 15 indicators have marginal predictive power of **less** than five percent and even the top-ranked macroeconomic indicators have marginal predictive power of less than 15 percent. This relative inability of indicators to predict crises may be due to

[3] However, some recent models (see Goldfajn and Valdéz (1995)) have highlighted the role of bank runs in precipitating currency crises.

several reasons. While developments during the 1990s are actively changing this (witness Asia in 1997-98), banking crises during the sample are still relatively rare vis á vis currency crises--there is a large discrepancy between the number of currency and banking crises in this study. Hence, detecting recurring patterns becomes more difficult in the smaller sample of banking crises. Also, pinning down the timing of a banking crisis requires a series of judgements about when banking sector "distress" becomes a full-fledged crisis.

The empirical evidence on the "predictability" of banking crises is still limited to a handful of papers. Papers that have followed the approach pioneered by Blanco and Garber (1986) for currency crises and have attempted to model the probability of banking crises on the basis of domestic and external fundamentals have encountered some of the problems highlighted in Table 3.1. Indeed, the results in the studies are conflictive. Eichengreen and Rose (1997) find that external conditions, specifically international interest rates play an important role in predicting banking crises. As to the domestic fundamentals, real exchange rate overvaluations, growth, and fiscal budget deficits appear to have predictive power. The composition of external debt also seems to matter. Other variables, including credit growth, they conclude, have little or no predictive ability. Demirguç-Kunt and Degratriache (1998) show some conflicting results. As to domestic fundamentals, they also find evidence that growth matters but find no evidence if favor of budget deficits. Real interest rates, credit growth, and M2/reserves figure prominently in their list of significant regressors. In any case, it appears that to improve upon our ability to predict banking crises we must look beyond macroeconomic indicators--an issue which we will take up later.

The annual indicators: What works?

Tables 3.3 and 3.4 present evidence on the performance of eight annual indicators that typically figure prominently in discussions of the causes of financial crises. The indicators include the fiscal variables stressed in the Krugman (1979) story of a currency crisis as well as the short-term debt exposure indicators stressed in recent theoretical and empirical explanations of the Asian crisis (see Calvo 1998, Calvo and Mendoza 1996, and Radelet and Sachs, 1998). As before, the indicators are ranked according to their marginal predictive power. The first column provides information on the noise-to-signal ratio, the second column lists the percent of crises accurately called, the third column provides information on the probability of crisis conditional on signaling, while the last column provides informant on the marginal predictive power of the variable.

Table 3.3 Annual indicators: Banking crises

Indicator	Noise-to-signal (1)	Percent of crises accurately called (2)	P(C|S) (3)	P(C|S)- P(C) (4)
1. Short-term capital flows/GDP	0.38	43	36.8	18.5
2. Current account balance/investment	0.38	38	36.1	18.4
3. Overall budget deficit/GDP	0.47	52	26.9	12.1
4. Current account balance/GDP	0.50	33	29.3	12.1
5. Central bank credit to the public sector/GDP	0.52	23	23.8	7.6
6. Net credit to the public sector/GDP	0.72	15	18.3	4.5
7. Foreign direct investment/	1.05	24	15.6	-0.6
8. General government consumption	1.44	15	10.0	-3.8

Source: The authors.

As to banking crises, the top indicator is the share of short-term capital inflows to GDP, this is consistent with the results in Eichengreen and Rose (1997) and it lends itself to the explanation that the banking sector becomes particularly vulnerable during cycles of short-term capital inflows, as this kind of capital flow is more likely to be intermediated through the domestic banking sector than other types of capital flows, such as foreign direct investment (FDI) and portfolio flows. Indeed, the share of FDI/GDP does poorly as a predictor of banking crises. Two of the fiscal variables, the budget deficit/GDP and central bank credit to the public sector do moderately well, yet the third--government consumption--does poorly. Hence, the role

of the public sector in fueling banking crises is somewhat mixed.

Without over interpreting the results, it appears that as regards banking crises, the composition of the current account matters, in the sense that the current account as a percent of investment does better than the current account as a share of GDP. The answer to this may have to do with the fact that investment may also be financed through the international issuance of bonds and stocks or overseas loans, while consumption may be more dependent on local bank credit.

As to currency crises, the annual indicators that perform well are those measuring current account imbalances. These results, notwithstanding, are still not representative of the broader empirical literature. As discussed in Kaminsky, Lizondo, and Reinhart (1998), most of the studies that have attempted to explain the k-period ahead probability of a currency crisis have had mixed results regarding the current account, with most studies finding it insignificant.

The various fiscal variables do moderately well, suggesting that first generation Krugman-type models have some to predict currency crises. By contrast with banking crises, the composition of capital inflows appears to have relatively little to add to our understanding of what drives a currency crisis. However, having said this, this result may be in part due to the fact that such a large share of the currency crises (as opposed to the banking crises) took place in the 1970s in an environment of highly regulated internal and external financial markets where portfolio flows were negligible.

Table 3.4 Annual indicators: Currency crises

Indicator	Noise-to-signal (1)	Percent of crises accurately called (2)	P(C|S) (3)	P(C|S)-P(C) (4)
1. Current account balance/GDP	0.41	56	43.2	19.5
2. Current account balance/investment	0.49	31	39.0	15.1
3. Overall budget deficit/GDP	0.58	22	36.4	11.5
4. Short-term capital flows/GDP	0.59	29	35.2	10.9
5. General government consumption	0.74	15	29.4	5.9
6. Net credit to the public sector/GDP	0.88	20	26.2	2.4
7. Central bank credit to the public sector/GDP	0.99	13	23.8	0.1
8. Foreign direct investment/GDP	1.00	24	21.7	0.1

Source: The authors.

While the list of variables we have examined is comprehensive, it is by no means exhaustive. The crises in Mexico, Thailand, Indonesia, and Korea have only highlighted the importance of tracking the extent of short-term indebtedness to assess vulnerability. Table 3.5 presents the extent of indebtedness in short maturities for a selected group of countries as of mid-1997. All the countries with debt-to-reserves levels in excess of 100 percent have all been casualties of financial turmoil in recent years, even if the speculative attacks have not ultimately succeeded, as in the case of Argentina.

Table 3.5 Short-term debt: selected countries
(Percent)

Country	Short-term debt/ total debt	Short-term debt/reserves
Asia		
Indonesia	24	160
Korea	67	300
Malaysia	39	55
Philippines	19	66
Thailand	46	107
Latin America		
Argentina	23	108
Brazil	23	69
Chile	25	44
Colombia	19	57
Mexico	16	126

Source: Bank of International Settlements, International Financial Statistics, World Bank.

Microeconomic indicators: selective evidence

The previous discussion has highlighted that banking crises may be more difficult to predict than currency crises on the basis of macroeconomic indicators. In this subsection we suggest that the assessment of the likelihood of a banking crisis may benefit from analyzing the evolution of a variety of microeconomic indicators of bank health. Gonzalez-Hermosillo (1996) and Rojas-Suarez (1998) provide some insights in this direction. Rojas-Suarez (1998) uses bank-

specific data from Colombia, Mexico, and Venezuela and applies the "signals" methodology described in Chapter 2 to this data to glean which items in bank balance sheet are most useful in predicting bank problems.

The results summarized in Table 3.6 do, indeed, highlight the usefulness of complementing macroeconomic analysis with bank-specific information in assessing the vulnerability of a banking sector to fall prey to crisis. As Rojas-Suarez (1998) argues, however, "traditional" indicators such as liquidity ratios and bank capitalization turn out to be less useful in the sense that these are "noisy" and likely to send many false alarms while missing many of the problem spots. At the other end, bank spreads and the interest rate banks offer on deposits appear to systematically signal which are the weak banks.

Table 3.6 Microeconomic indicators: Banking crises

Indicators	Percent of crises accurately called	Noise-to-signal
1. Bank lending-deposit spread	73	0.28
2. Interbank debt growth	80	0.35
3. Interest rate on deposits	80	0.47
4. Rate of growth on loans	58	0.72
5. Net profits to income	60	1.14
5. Operating costs to assets	40	1.59
6. Change in equity prices	7	2.00
7. Risk-weighted-capital-to-asset ratio	7	2.86

Source: Rojas-Suarez (1998).

Goldstein (1998) stresses the role played by bank exposure to the property sector as an indicator to monitor in the context of early warnings of banking crises, noting that in many of the affected Asian countries estimates of the share of bank lending to the property sector exceeded 25 percent. Banking sector external exposure, measured as foreign liabilities as a percent of foreign assets also appear to be a worthy addition to the list of sectoral or microeconomic indicators of banking sector indicators.

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APPENDIX A: DATA AND DEFINITIONS

Crisis index: The index is a weighted average of exchange rate and reserve changes, with weights such that the two components of the index have equal conditional volatilities. Since changes in the exchange rate enter with a positive weight and changes in reserves have a negative weight attached, readings of this index that were three standard deviations or more above the mean were cataloged as crises. For countries in the sample that had hyperinflation, the construction of the index was modified. While a 100 percent devaluation may be traumatic for a country with low-to-moderate inflation, a devaluation of that magnitude is commonplace during hyperinflations. A single index for the countries that had hyperinflation episodes would miss sizable devaluations and reserve losses in the moderate inflation periods, since the historic mean is distorted by the high-inflation episode. To avoid this, we divided the sample according to whether inflation in the previous six months was higher than 150 percent and then constructed an index for each subsample. Our cataloging of crises for these countries coincides fairly tightly with our chronology of currency market disruptions. Eichengreen, Rose, and Wyplosz (1995) also include interest rates in this index, however, our data on market-determined interest rates for developing countries does not span the entire sample.

The indicators:

Sources: International Financial Statistics (IFS), International Monetary Fund; Emerging Market Indicators, International Finance Corporation (IFC); World Development Indicators, the World Bank, when data was missing from these sources, central bank bulletins and other country-specific sources were used as supplements. Unless otherwise noted, we used **12-month percent changes**.

1. M2 multiplier: The ratio of M2 to base money, (IFS lines 34 plus 35) divided by IFS line 14.

2. Domestic credit/nominal GDP: IFS line 52 divided by IFS line 99b (interpolated). Monthly nominal GDP was interpolated from annual or quarterly data.

3. Real interest rates on deposits: IFS line 60l, monthly rates, deflated using consumer prices (IFS line 64) expressed in percentage points.

4. The ratio of lending rates to deposit rates: IFS line 60p divided by IFS line60l; was used in lieu of differentials to ameliorate the distortions caused by the large percentage point spreads observed during high inflation. In levels.

5. "Excess" real balances: M1 (IFS line34) deflated by consumer prices (IFS line 64) less an estimated demand for money. The demand for real balances is determined by real GDP (interpolated IFS line99b), domestic consumer price inflation, and a time trend. Domestic inflation was used in lieu of nominal interest rates, as market-determined interest rates were not available during the entire sample for a number of countries; the time trend (which can enter log-linearly, linearly, or exponentially) is motivated by its role as a proxy for financial innovation and/or currency substitution. Excess money supply (demand) during pre-crisis periods (mc) is reported as a percent relative to excess supply (demand) during tranquil times (mt)--that is, 100 x (mc-mt)/mt.

6. M2 (in US dollars)/reserves (in US dollars): IFS lines 34 plus 35 converted into dollars (using IFS line ae) divided by IFS line 1L.d.

7. Bank deposits: IFS line 24 plus 25.

8. Exports (in US dollars): IFS line 70.

9. Imports (in US dollars): IFS line 71.

10. The terms of trade: the unit value of exports (IFS line 74) over the unit value of imports

(IFS line 75). For those developing countries where import unit values (or import price indices) were not available, an index of prices of manufactured exports from industrial countries to developing countries was used.

11. The real exchange rate: This measure used is based on consumer price indexes (IFS lines 64) and is defined as the relative price of foreign goods (in domestic currency) to the price of domestic goods. If the central bank of the home country pegs the currency to the dollar (Deutsche mark), the relevant foreign price index is that of the United States (Germany). Hence, for all the European countries the foreign price index is that of Germany while for all the other countries, consumer prices in the United States were used. The trend was specified as, alternatively, log-linear, linear, and exponential; the best fit among these was selected on a country-by-country basis. Deviations from trend during crisis periods (dc) were compared to the deviations during tranquil times (dt) and are shown in Figures 2 and 3 as a percent of the deviations in tranquil times (i.e.,100 x (dc-dt)/dt).

12. Reserves: IFS line 1L.d**.**

13. Domestic-foreign interest rate differential on deposits: Monthly rates in percentage points. IFS lines 60l. Interest rates in the home country are compared with interest rates in the United States (Germany) if the domestic central bank pegs the currency to the dollar (Deutsche mark). The real interest rate is given by $100 \times [((1+ i_t)p_t / p_{t+1-1}]$.

14. Output: For most countries, the measure of output used is industrial production (IFS line 66). However, for some countries (the commodity exporters) an index of output of primary commodities is used (IFS lines 66aa).

15: Stock returns (in dollars): IFC global indices are used for all emerging markets; for industrial countries the quotes from the main bourses are used.

16. Overall budget balance/GDP: Consolidated public sector balance as share of nominal GD